STATIC VOLTAGE STABILITY ASSESSMENT WITH CONTINUATION POWER FLOW

SHAHNURRIMAN BIN ABDUL RAHMAN

A project report submitted in partial fulfilment of the

requirements for the award of degree of

Master of Engineering (Electrical-Power)

Faculty of Electrical Engineering

Universiti Teknologi Malaysia

JANUARY 2012

In The Name of Allah SWT of the Most Gracious and The Most Merciful

"…and say 'O my Lord increase me in knowledge.."

The sublime Quran

DEDICATION

This project report is dedicated to:

My beloved father Abdul Rahman bin Laham and my beloved mother Ramlah bt Lambak, thanks for their love, lots of cares and full prayers.

My beloved sister Syarinah Nur and Fariza, thanks for their kindness ,motivation and information over the entire period of my study.

My beloved brothers Shanilman and Mohd Rashidi for always giving me strength and strong motivation for me to finish this work.

ACKNOWLEDGEMENT

In the name of ALLAH, Most Generous and Most Merciful

It is with the deepest sense of gratitude of the Almighty ALLAH who gives strength and ability for me to complete this thesis. All good aspirations, devotions and prayers are due to His mercy and blessing that had helped me throughout the entire of this project.

First and foremost, I would like to dedicate my fully sincere gratitude to my very supportive supervisor Assoc. Prof Dr Mohd Wazir bin Mustafa for giving me a chance to conduct this interesting project besides his guidance and patience throughout the period of this project. In this opportunity also I would like to thank to:

My beloved father and mother for their encouragement and full prayers over the entire period of my study.

All of my brothers and sister for their supports, motivations, lots of helpfulness throughout my study.

My friends for their helpfulness for the entire of my study and my project work also specially thanks to Sharifah Nur Asyikin in helping me and her encouragement for me to finish this work and also everyone that involved in this project.

ABSTRACT

The purpose of this project is to review and investigate the capability of Continuation Power Flow (CPF) method in assessing the static voltage stability of a network. CPF is a method that being introduced to overcome the singularity problem in conventional Newton-Raphson method. In order to analyse the effect of contingency to the network, two types of contingency categorised as generation outage and line outage being applied. The effect of both types of contingency on Maximum Loading Point (MLP) and Megawatt Margin (MWM) is focused as the indicator of static voltage stability. Simulation results demonstrated that for every condition of the system, the system should be able to provide its MLP and MWM values. A set of ranking based on its severity to the system then being ranked. This will help any electric utility planners and also the operators to plan for the most suitable remedial actions to avoid the system moves toward voltage instability. The ranking has been divided into three categories such Unacceptable, Significant and Acceptable. The study used IEEE 14-Bus and IEEE 30-Bus Test System as the study case and Matlab and Power System Analysis Toolbox (PSAT) as the simulation software. The simulation results on both system has proven that PSAT able to analyse the static voltage stability.

ABSTRAK

Tujuan projek ini dijalankan adalah bertujuan untuk mengkaji dan mengenal pasti kemampuan kaedah Aliran Kuasa Secara Berterusan (CPF) dalam menilai kestabilan voltan statik bagi sesuatu rangkaian. CPF merupakan satu kaedah yang diperkenalkan bagi mengatasi masalah ketunggalan di dalam teknik Newton-Raphson yang dahulu. Dalam menganalisa kesan kontigensi kepada sesuatu rangkaian, dua jenis kontigensi iaitu gangguan generasi dan gangguan talian digunakan. Kesan kedua-dua kontegensi pada Titik Muatan Maksima (MLP) dan Mega Watt Margin (MWM) difokuskan sebagai petunjuk kepada kestabilan voltan statik. Keputusan simulasi menunjukkan bahawa untuk setiap keadaan sistem, ia mampu untuk memberikan nilai MLP dan MWM yang tersendiri. Satu set kedudukan berdasarkan tahap bahaya kepada sistem kemudian ditentukan. Ini mampu membantu kepada penyedia elektrik dan pekerja untuk merancang cara yang terbaik bagi mengelakkan sistem untuk berada di kawasan voltan tidak stabil. Kedudukan ini boleh dibahagikan kepada tiga kategori iaitu Tidak Boleh Diterima, Signifikan dan Boleh Diterima. Kajian ini menggunakan IEEE-14 dan IEEE-30 Bus Sistem Ujian sebagai kes ujian dan Matlab serta PSAT sebagai perisian simulasi. Hasil simulasi pada kedua-dua sistem menunjukkan bahawa PSAT mampu untuk menganalisis kestabilan voltan statik.

TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

LIST OF CHART

LIST OF APPENDICES

LIST OF SYMBOLS AND ABBREVIATIONS

P_i	-	Power at bus i^{th}
Q_i	-	Reactive Power at bus i^{th}
P_{Gi}	-	Power Generation at bus i^{th}
Q_{Gi}	-	Reactive Power Generation at bus i^{th}
P_{Di}	-	Power Demand at bus i^{th}
Q_{Di}	-	Reactive Power Generation at bus i^{th}
P_{Dio}	-	Original Power Demand at bus i^{th}
Q_{Dio}	-	Original Reactive Power Demand at bus i^{th}
θ	-	Vector angle of bus voltage
V	-	Bus Voltage magnitudes
λ	-	Load parameter
e_k	-	Appropriate row vector
x_k	-	State variable chosen continuation parameter
η	-	Predicted value of state variable
σ	-	Step size
p.u	-	Per unit
λ_{max}	-	Maximum Loading Parameter
MWM	-	Megawatt Margin
MMWM	-	Maximum Megawatt Margin
MLP	-	Maximum Loading Point

CHAPTER 1

INTRODUCTION

1.1 Background

Nowadays, voltage stability is a crucial issue as the rapid increase in the load demands. This issue has also drawn a large attention when the systems operate near the critical limit due to the economical and environmental constraint for preparing new power plants and transmission lines. Two parameters that should be the centre of attention in any power system network are the issue of reliability and also the security. In reliability, it is meant that the system should have enough reserve to cope with any additional demand. By security, it is meant that the system is able to cope and handle the occurrence of any disturbance happen to the system by able to recover to initial state condition. When it is involves with security concerns, voltage stability would become to the highest priority.

Voltage stability can be described as the capability of the system to maintain the adequate voltage under normal operating conditions and after the disturbances arise.[2] Whenever in some or all buses experiences voltage decrease due to insufficient power delivered to loads, it can be called as the voltage stability problem Sometimes due to this problem, serious blackout may occur to the system and causes

severe social and economic problems. These will violates mission and also the vision of power sector to have a secure and reliable power supply to the consumers.

Therefore methods to analyse and examine the voltage stability in power system become important tools to the utilities. By using these methods, an early prediction can be made to ensure the system is stable and the network security is stable. Here a method called Continuation Power Flow Method (CPF) is being discussed to make the assessment on the static voltage stability of the network. The assessment will be done to the IEEE 14 and 30 test systems by using Matlab by considering the possible contingencies

1.2 Problem Statement

Conventional power flow computational started with Gauss Seidel method and then an alternative technique called Newton-Raphson (NR) being introduced as it is reliable, offers less computational time and more economical in terms of storage requirement. Yet, it is found that the Jacobian of the NR power flow calculation becomes singular when it reaches ill conditioned point. This issue becomes more critical for a heavy loaded system. Commonly in NR when the power flow approaches the critical point, it will diverge and give a large error

1.3 Objectives

The objectives for this project are:

i. To review the static voltage stability using continuation power flow method.
ii. To simulate contingency to IEEE 14-Bus and 30-Bus Test System.
iii. To analyse contingencies and their impact to the static voltage stability.
iv. To rank possible contingencies based on their severity to the system by using contingency ranking.

1.4 Scope of Work

The scope of this project will cover on:

i. Concept of static voltage stability, power system contingency in power system
ii. Continuation Power Flow Method
iii. Simulation using Power System Analysis Toolbox (PSAT)
iv. IEEE 14-Bus and 30-Bus Test System by considering contingency.

1.5 Project Outline

This report consists of six chapters, including this chapter which introducing the project report.

In Chapter 2, three methods of load flows such the Gauss-Seidel Method, Newton-Raphson and Saddle Node Bifurcation (SNB) being covered in terms of their background and operation.

Chapter 3 discusses on Continuation Power Flow Method (CPF). In CPF three important steps that being highlighted are prediction step, corrector step and also the parameterization. Contingency that being applied to the system also will be discussed in this chapter.

Chapter 4 explains the simulation that being carried out to the IEEE 14-Bus and IEEE 30-Bus System. The conditions of the test system during no contingency and under effect of contingency were considered during the simulation.

Chapter 5 is about the results and discussion being made based on the simulation. The results will show the effect of contingency to the system based on the MLP and MWM values before the contingency ranking being made.

Lastly, chapter 6 consists of the conclusion of the project and also some recommendation for future works.

REFERENCES

1. Majid Poshtan, Parviz Rastgoufard, and Brij Singh, "*Contingency Ranking for Voltage Stability Analysis of Large-Scale Power System*",Proceeding of IEEE/PES Power System Conference and Exposition.

2. Venkataramana Ajjarapu, Member, IEEE Colin Christy, Student Member, IEEE , "*The continuation power flow: A tool for steady state voltage stability analysis*".

3. M.A. Kamarposhi, H. Lesani , "*Contingencies Ranking for Voltage Stability Analysis using Continuation Power Flow Method*", Electronic and Electrical Engineering, 2010".

4. Pengcheng Zhu, Gareth Taylor and Malcolm Irving, Full Member, IEEE , "A Novel Q-Limit Guided Continuation Power Flow Method ",IEEE,2008.

5. M. Z. Laton, I. Musirin,T. K. Abdul Rahman, "Voltage Stability Assessment via Continuation Power Flow Method" Int. Journal Of Electrical And Electronic System Research, Vol.1, June 2008

6. J.Jasni, S.Bahari, N. Mariun, M.Z.A Kadir, H. Hizam, "State of the Art for Voltage Collapse Point Approximation Using Continuation Power Flow" European Journal of Scientific Research, Vol.22 No.1 (2008), pp.98-105.

7. Li-Jun Cai, and István Erlich, Senior Member IEEE , "*Power System Static Voltage Stability Analysis Considering all Active and Reactive Power Controls -Singular Value Approach*", PowerTech 2007

8. Arthit Sode-Yome, Member, IEEE, Nadarajah Mithulananthan, Member, IEEE, and Kwang Y. Lee, Fellow, IEEE, "*A Maximum Loading Margin Method for Static Voltage Stability in Power Systems*", IEEE Transactions on power systems, vol. 21, No. 2, May 2006.

9. Karamitsos Ioannis and Orfanidis Konstadinos , "*An Analytical approach for Dynamic Voltage Stability Analysis in Power Systems*" , Proceedings of the 5th WSEAS International Conference on Applications of Electrical Engineering, Prague, Czech Republic, March 12-14, 2006 (pp36-38).

10. Badrul H. Chowdhury, Student Member, IEEE and Carson W. Taylor, Fellow, IEEE, "*Voltage Stability Analysis: V –Q Power Flow Simulation Versus Dynamic Simulation*" , IEEE TRANSACTIONS ON POWER SYSTEMS, VOL. 15, NO. 4, NOVEMBER 2000

11. T. Van Cutsem ,C. Moisse , R. Mailhot ,"*Determination of secure operating limits with respect to voltage collapse"* , IEEE Transactions on Power Systems, Vol. 14, No. 1, February 1999 .

12. Byung Ha Lee and Kwang Y. Lee. Senior Member , "*Dynamic and Static Voltage Stability Enhancement of Power Systems"*, LEEE Transactions on Power Systems, Vol. 8, No. 1, February 1993.

13. Huadong Sun ,Xiaoxin Zhou ,Ruomei Li , "*Accuracy Analysis of Static Voltage Stability Indices Based On Power Flow Model*", China Electric Power Research Institute, Qinghe, Beijing, China .

14. F.Milano, "An Open Source Power System Analysis Toolbox",IEEE Transactions on Power Systems.

15. Dilson A. Alves,Luiz C.P. da Silva , Carlos A. Castro ,Vivaldo F. da Costa , "*Alternative parameters for the continuation power flow method*", Electric Power Systems Research 66 (2003) 105/113.

16. Khalid Mohamed Nor, "Power System Analysis with computing techniques",Perpustakaan Negara Malaysia Data Catalouge-in Publication Data.

17. A. Anbarasan, M. Y. Sanavullah, "*Identification of Maximum Loading Point in Power System under Critical Line Outage Condition*", European Journal of Scientific Research, pp 274-282, 2012.

18. Badrul H.Chowdhury, "*Load-Flow Analysis in Power System" Handbook of Electric Power Calculation*",Section 11.

19. Hinke Osinga, "*Nonlinear Dynamics & Chaos*",EMAT33100,pp 16-24.

20. Mr. Ahmed N. B. Alsammak, " Bifurcation and Voltage Collapse in the Electrical Power Systems", AL-Rafidian engineering Vol 13, No.1 ,2005

21. H.A.Al-Awami, "*Power Flow Control to Determine Voltage Stability Limit by Using the Continuation Method*", unpublished